THE

JOURNAL OF GEOLOGY

SEPTEMBER–OCTOBER, 1899

THE OZARKIAN AND ITS SIGNIFICANCE IN THEORETICAL GEOLOGY.

I. THE OZARKIAN.

IN 1886 I published a paper entitled "A Post-Tertiary Elevation of the Sierra Nevada, as shown by the River-beds." [1] Again in 1891 I published a paper on "The Mutual Relations of Land Elevation and Ice Accumulation during the Quaternary Period." [2] The following paper may be regarded as a continuation of the lines of thought suggested by the two preceding.

By continued reflection on the enormous changes that occurred in the western part of the continent at the end of the Tertiary, I have been led to recognize the existence of an epoch of long duration and of great importance immediately preceding the time of the invasion of the ice sheet. On account of its great importance this epoch certainly deserves a distinctive name. For want of a better, I adopt that of the "Ozarkian," given it by Hershey.

History of the name.—The epoch was first recognized by Hilgard and more distinctly by McGee, as the post-Lafayette uplift,

[1] Am. Jour. Sci., Vol. XXXII, p. 167, 1886.

[2] Bull. Geol. Soc. Am. Vol. II, p. 329.

shown by extensive erosion of the Lafayette gravels all over the southern states. But a distinctive name was first given it by Hershey,[1] who called it Ozarkian in commemoration of its work in the formation of the remarkable gorges of the region of the Ozark Mountains. He, however, fully recognized its importance as a time of general uplift and erosion, but regarded it as only an episode comparable with the Kansan or Iowan episodes of the Glacial epoch. The name was adopted, though somewhat reluctantly, by McGee (Sci. III, 796, 1896), and its importance more fully recognized,[2] but he regards it as belonging to the Pliocene and not the Quaternary. This point we shall discuss later. A little later (Am. Geol. XVII, 389, 1896) Upham also adopts the name, and, like Hershey, refers it to the early Quaternary, but advances it to a *primary* division of that period comparable with the Glacial. But even yet, it seems to me, its full importance is scarcely recognized unless it be by McGee, and its true significance entirely overlooked. Indeed both its importance and its significance are brought out in strong relief only by the study of its phenomena in the western part of the continent and especially in California.

If with Upham we divide the Quaternary period into three epochs, the Ozarkian, the Glacial, and the Champlain, then the Ozarkian was by far the longest, in fact, longer than both the others put together. Or again, if the Quaternary be divided into two epochs, the Ozarkian and the Glacial, the Champlain being merged into the Glacial, as is commonly done by European geologists, then of the two, the Ozarkian is by far — perhaps by many times — the longer. In many ways the Ozarkian is strongly contrasted with the other epochs of the Quaternary. If, for example, we adopt the division into three epochs, these are characterized each in its peculiar way; the first, by elevation; the second, by ice accumulation; the third, by depression; the first, by immense erosion; the second, by glaciation and drift deposit; the third, by stratified deposits in seas and lakes.

[1] Science III, 620, 1896.

[2] "The reference of the Ozarkian to the Pleistocene would multiply by many times the commonly recognized duration of that period." McGee, Sci. III, 796, 1896.

The Ozarkian has heretofore attracted little attention, because until very recently geological history was supposed to be recorded only in stratified rocks and their contained fossils; but this being a period of continental elevation and enlargement, it has left no strata exposed to view. Geological history was at that time recorded only by erosive work. So far as stratified rocks and fossils are concerned, this is a period of lost record—it is a *lost interval.*

I said that the real importance and significance of this epoch is best seen on the western part of the continent. I must justify this assertion by a comparison of the phenomena in different parts of the continent.

1. *The eastern part.*—In the eastern part of the continent, the work of erosion of this time is seen in the so-called old river-beds deeply underlying the present beds and extending beyond their limits on each side, and especially continuing beyond the limits of the present continent, as submerged channels trenching the submerged continental shelf, notching deeply its margin and opening out into the abyssal waters of the true oceanic basin. It is shown also not only in the deep gorges of the Ozark region, not only in the deep and widespread erosion of the Lafayette gravels in the south, but also in the highly emphasized topography underlying the drift all over the glaciated region of the north. By means of the submerged channels the amount of vertical elevation of the eastern portion of the continent has been estimated as certainly not less than 3000–5000 feet and may have been much greater. Similar evidences of elevation are found on the Pacific coast and also on the coasts of Europe and of Africa. We have every reason to believe that it was a time of almost universal continental elevation and enlargement.

Heretofore these old rivers of the east have been referred, like those of the west, to the Tertiary times and called Tertiary river-beds; although it is admitted that they were occupied and deepened by the ice of the Glacial times. The Tertiary erosion was supposed to have graded insensibly and continuously into that of the Glacial, but the greater part was attributed to the

Tertiary; and the post-Tertiary erosion was supposed to be wholly Glacial. According to my view, on the contrary, the post-Tertiary erosion was by far the greater and was pre-Glacial in time, *i. e.*, Ozarkian.

In the eastern portion of the continent, therefore, the Ozarkian grades into the Tertiary, but is well marked off from the present by the depression and sedimentation of the Champlain.

2. *The mid-continental or plateau region.*—In the plateau region, on the contrary, the Ozarkian work is sharply marked off from the Tertiary, but grades insensibly into that of the present.

It is well known that the plateau region has been rising ever since the end of the Cretaceous—that from being the lowest part of the interior continental basin, it has become the highest part of the continental arch. The amount of elevation during this time has been at least 20,000 feet, about 12,000 of which has been carried away by erosion, leaving still 8000 feet of general elevation. Of this enormous general erosion, the largest part—shown by the receded and still receding cliffs—probably belongs to the Miocene. The canyon-cutting is certainly post-Miocene. The outer canyon (of the Grand Canyon) ten to fifteen miles wide and 3000 feet deep, belongs to the Pliocene; while the inner gorge, 3000 feet deep but very narrow, belongs to the post-Pliocene, *i. e.*, to the Ozarkian and the present.

I said the Tertiary work is sharply marked off from the Ozarkian but the Ozarkian grades insensibly into present. The evidence of this is given by Dutton, as follows:

Between the Pliocene work of the formation of the outer canyon, and the subsequent work—Ozarkian to present—the cutting of the inner gorge, there was an interval of rest marked by a wide shelf between the two. The rising and the down-cutting was continuous during the Pliocene until finally the river reached its base level of erosion and rested from further downward cutting and commenced to sweep from side to side widening its channel, until the canyon walls were nearly ten miles apart. Then began the Ozarkian rise and the beginning of the

cutting of the inner gorge, which has continued to the present time. The elevation during the Tertiary was regional, the elevation which commenced with the Ozarkian was continental or even more widespread. In the east there was a sharp demarcation of the Ozarkian from the present erosion by the Champlain depression and sedimentation; which depression, as I suppose, was determined by the weight of the ice sheet. But in the plateau region there was no ice sheet — it did not extend so far — and therefore there was no depression and therefore no interruption of the erosion to the present time; for the rising is still progressing. The whole series of phenomena in this region may be well explained by a local rise continuous from the end of the Cretaceous till now, except that it was interrupted at the end of the Pliocene by the Lafayette depression of McGee and afterwards greatly enhanced by the general continental elevation of the Ozarkian.

3. *Sierra region.* — But it is in the Sierra region alone that we find the Ozarkian erosion-work sharply marked off both from the Tertiary on the one hand and from the present on the other. It is here therefore that the distinctive Ozarkian work can be best studied.[1]

Brief history of the Sierra.—The Sierra Nevada, as is well known, was formed at the end of the Jurassic by lateral pressure and strata-folding in the usual way. What kind of a mountain it was at that time, how high, and what its configuration we know not; for the continuous erosion of the Cretaceous and Tertiary times had nearly swept it clean away. The cycle of its mountain life had reached its last stages. By continuous erosion it had been reduced to a peneplain, with its wide-sweeping curves of broad shallow channels and low-rounded divides. The rivers had reached their base levels and rested. This was the work of the Cretaceous and Tertiary.

Then came the post-Tertiary rejuvenation of the mountain

[1] As the term *Ozarkian* had already been used by Broadhead for a Lower Silurian series in the Ozark region (Am. Geol., XI, p. 260, 1893) there may be an admissibility of its use in this connection. If so, I would propose the name *Sierran* as far more appropriate.

life,[1] by the formation of a fissure on the eastern slope, the heaving of the whole mountain block on its eastern side with a great eastern fault-scarp, ; the transference of the crest to the extreme margin with great increase of the western slope and consequent revival of the erosive energy of the rivers. Coincident with this in middle California there was a great outpouring of lava which ran in streams down the western slope, filling up the old river beds, and displacing the rivers. The displaced rivers, with recently and fiercely aroused energy, immediately commenced cutting new channels, which are now 3000 to 6000 feet deep, and far below the old; so that these latter are left with their lava-covered gravels high up on the present divides This was the work of the Ozarkian. This intensely interesting geological story has been so often told that we only recall here its outlines in order to apply them to the case in hand.

In southern California, beyond the limits of the lava flows this post-Tertiary elevation and revival of erosive energy was fully as great, or even greater than in middle California; but the rivers were not displaced, and therefore they continued to cut in the same places, but to far deeper levels ; so that the margins of the wide old river beds with their gravels are left hung up high on the sides of the present canyons.[2] The distinction, however, between the wide shallow tertiary troughs and the deep narrow post-Tertiary canyons is equally sharp here.

We have spoken thus far only of the deep canyons which trench the western slope as being of post-Tertiary origin ; but the same is true also of the whole scenery of the high Sierra. It all belongs to the post-Tertiary, and its bold, rugged, savage grandeur is due to its extreme recency. The wildness of youth has not been yet tempered and mellowed by age.

It is evident then that the Ozarkian is here sharply marked off from the Tertiary. How is it in regard to its relation to the present? In the lower parts of the canyons the Ozarkian grades insensibly into the present, for the rivers are still cutting. But

[1] Am. Jour. Sci., Vol. XXXII, 167, 1886.

[2] Am. Jour. Sci., Vol. XXXII, 174, 1886.

in their upper parts the two are separated by the glacier erosion. The upper canyons were occupied by glaciers, and the comparison of these upper with the lower canyons shows that while their forms were modified, and perhaps their depths somewhat increased, they were not made by this agency. This was mainly the work of the post-Tertiary but pre-Glacial times, *i.e.*, of the Ozarkian. But the glaciation serves to show how much has been done by water since the Glacial, *i. e.*, during the present times; and we find it very insignificant.

In conclusion, no one who sees and reflects upon the prodigious work done in the Sierra since Tertiary times can resist the conviction that even making all due allowance for exceptional energy and rapid work, determined by high slope and also for other causes of rapid work explained in a previous paper,[1] the time necessary must have been enormous — many times as great as any reasonable estimate of the duration of the Glacial epoch.

II. SOME MODIFICATIONS OF MY PREVIOUS VIEWS.

In the article already alluded to, on the "Relation of Land Elevation and Ice Accumulation" I attempted to reconcile the two antagonistic views in regard to the attitude of land during the Glacial epoch. According to some writers the land in high latitude regions was greatly *elevated;* according to others it was on the contrary *depressed.* According to the one, the intense cold and ice accumulation was the direct result of the elevation, and a subsequent depression produced a moderation of the climate and a melting and final disappearance of the ice; according to the other, the ice accumulation was not coincident with the elevation and, therefore, there must have been some other cause for the cold and ice accumulation. In the paper referred to I showed that all the phenomena might be satisfactorily explained by supposing that the elevation was the cause of the cold — the cold the cause of the ice accumulation — the weight of the accumulated ice the cause of the depression — the depression the cause of returning

[1] Origin of Transverse Mountain Valleys, Univ. Chronicle, Vol. I, No. 6, p. 179, 1898.

warmth — the warmth the cause of the melting and retreat of the ice, and finally that the removal of the ice-load was the cause of the re-elevation to the present condition; but — and this is the distinctive feature of my view — that in all these cases *the effects lagged behind the causes.* I showed that this was so in all cases of accumulated effects, but would especially be true in this case. To illustrate these relations I used a diagram which I here pro-

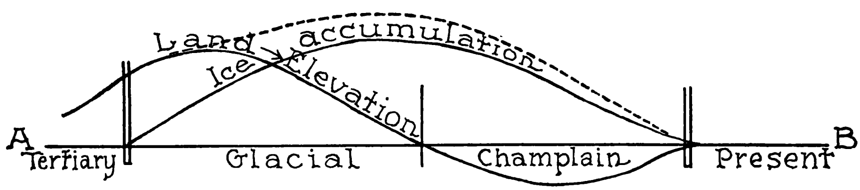

FIG. 1.— Diagram showing the relations of land elevation and ice accumulation during the Quaternary. *AB* — course of time and also the present status of earth crust. The dotted line shows elevation if it had not been interfered with by the ice-load.

duce. The legend will sufficiently explain it. By this view the Quaternary consists of two epochs, the Glacial and the Champlain, of nearly equal lengths. The one characterized by elevation and cold, the other by depression and warmth, but the extreme of ice accumulation lagged behind the extreme of elevation as seen in the figure.

I am more and more convinced that the principle of lagging is a true one and even more important than I at that time supposed. I now believe that I did not at that time make the lagging, especially in the matter of the accumulation of the ice-load, great enough. We must make a distinction in this regard between the intensity of the cold and the thickness of the accumulated ice. The cold probably responded somewhat promptly to the land elevation, but not so the ice accumulation. This was a very slow process and might lag to any degree behind the elevation and the cold. This we now proceed to show.

1. Snowfall depends on cold, but still more upon moisture.

Now there is nothing in the way of supposing—but on the contrary much reason to believe—that the period of great elevation was one of comparative dryness and that the climate became moister in the latter part when the elevation was not so great. This would make the ice accumulation lag behind the elevation and the cold.

2. But again: We must, of course, make a wide distinction between the annual snowfall and the rate of accumulation; for this latter is the result only of the annual *excess* of snowfall over waste by melting and evaporation, and this excess may be to any degree small.

3. As it is, the *thickness* and therefore the *weight* of the snow that we are here concerned with, it must be remembered again that there is still another and much more important source of waste antagonizing local accumulation and therefore increase of thickness, viz., the run-off—not the run-off as water but as ice by glacial motion. After a certain thickness is attained this run-off completely balances the annual excess over waste by evaporation and melting, and prevents, farther increase of thickness. This is the case now in all glacial regions. In the Alps, the Himalayas, etc., there is no indefinite increase of thickness because the run-off by glacial motion completely balances the annual excess. Similarly in Greenland, and the Antarctic continent although there is great excess of snowfall over waste by evaporation and melting, yet there is no increase in the thickness of the ice sheet because the excess is balanced by the run-off of the ice into the sea and the formation there of icebergs which are carried away by oceanic currents.

So also in Glacial times, after a certain thickness of snow had accumulated on any given area—say the Canadian highlands—the farther increase would be prevented, because balanced by the ice-sheet motion in all directions. Any increase of thickness would require not only excess but *increase of excess* and would be extremely slow because always kept in check by the increased run-off.

To sum up: Suppose, then, the highlands about Hudson

Bay to have been the center of elevation, of ice accumulation and of radiating run-off: Suppose farther, that the elevation commenced about the end of the Pliocene and was the cause of the cold. Then considering the previous warmth of the Tertiary times, it is probable that the elevation would go on for a long time and reach a considerable degree before there would be any snowfall at all in this region, and still much longer time before there would be annual excess over waste by evaporation and melting, *i. e.*, before there would be *perpetual snow*. After perpetual snow was reached, under the effect of the ice-sheet motion tending ever to bring about equilibrium, the increase of the thickness of the ice sheet must have been extremely slow. In fact, it is evident that no such thickness as actually occurred could

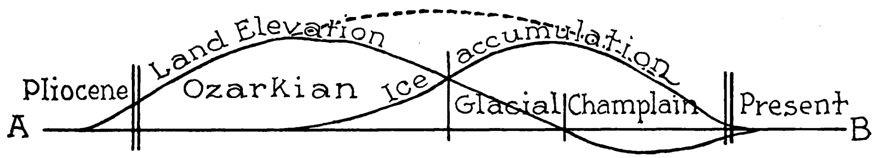

FIG. 2.—Diagram showing supposed relation of land elevation to ice accumulation, as now revised.

have been attained at all, but for the subsidence of the earth-crust under the weight of the ice. The increased thickness was conditioned upon and waited on the subsidence. I believe, therefore, that an increase of one inch per annum would be an extravagant estimate. At this rate it would take 150,000 years to make a thickness of 12,000 feet, which is the estimate of Dana. To this must be added the much greater time before the perpetual snow was formed at all.

Under the light of these estimates and especially of these new views of a long Ozarkian epoch preceding the glacial epoch, I would therefore modify my previous diagram, making the beginning of the ice accumulation much later and making both the Glacial and the Champlain much shorter than before, as shown in the revised diagram, Fig. 2. The greater distinctness of the Ozarkian from the Glacial is shown

III. SIGNIFICANCE OF THE OZARKIAN.

In my papers on *Critical Periods in the History of the Earth*, in 1877 and in 1898[1] I try to show that there are periods of great and widespread changes in the earth's crust, in climate, and in organic forms. These I call "critical periods" and insist that they separate the primary divisions of geological, time, viz., the *eras*. Being periods of great elevation and enlargement of continents, they are to a great extent "lost intervals," *i. e.*, periods in which the usual record of stratified rocks and contained fossils is interrupted. The last of these was the Quaternary. The Ozarkian was largely a lost interval so far as stratified record is concerned.

Great cycles in the evolution of the earth.—Now an era, *i. e.*, the time from one critical period to another, must be regarded as one great cycle of widespread changes; during which, however, there may have been and indeed undoubtedly were, subordinate and more local cycles. Such a great cycle was the Paleozoic, very regular in its course in this country. Such another great cycle was the Mesozoic, but affected in this country with a well marked subordinate division at the end of the Jurassic. Still another such great cycle and again very regular in this country was the Cenozoic, and such another, I am convinced, is even now commencing. I have called it the Psychozoic.

I have supposed these to be cycles in the evolution of the earth. They are, therefore, such in every department alike. They are cycles in the evolution of earth-forms, *constructively*, *i. e.*, by *interior* forces in continental elevation and mountain formation. They are cycles in the evolution of earth-forms, *destructively*, *i. e.*, by *exterior* forces and erosive sculpturing. They are cycles of evolution in climatic conditions. And, finally, as the result of all these, they are also cycles in the evolution of organic forms and their geographical distribution. Most of these various forms of cyclical movement I have discussed in my previous papers, especially that in 1895. These, therefore, I merely

[1] Am. Jour., Vol. XIV, 99, 1877. Bull. Geol. Dept. Univ. Cal., Vol. I, 314, 1895.

mention and pass on. Some, however, I discuss fully now for the first time.

1. *Cycles of constructive forms.*—Of the four great kinds of earth movements treated of in my address as President of Geological Society of America, December 1896,[1] the greatest, viz., that by which are formed oceanic basins and continental arches, being determined by unequal radial contraction in the secular cooling of the earth, which in its turn is the result of an original heterogeneity in the density and especially in the conductivity of different parts of the earth, must have a cycle coëxtensive with the life of the earth itself, and therefore may be left out in this discussion. But superimposed on this greatest, there are other cycles of oscillations of the earth's crust over wide areas—of continental elevation and depression, accompanied with the formation of great mountain ranges. These are the cycles of next importance, and with which we are here concerned; for they determine all other cycles mentioned above, and therefore the occurrence of what I call critical periods. They are demonstrated by the widespread unconformities which occur at these times. Upon these, again, are superimposed still lesser cycles which, however, do not concern us here. I have sufficiently treated of these, both great and small, elsewhere, and therefore pass on.

2. *Cycles of climatic conditions.*—Coincidentally with the changes by continental elevation and depression with their attendant mountain-making, there have undoubtedly been concurrent changes in climatic conditions of many kinds, especially of temperature. These changes were, on the whole, probably gradual throughout the era, but culminate and oscillate in the critical period which closed it and constituted one of its most marked features. The two most conspicuous examples are those which occurred at the end of the Paleozoic and at the end of the Tertiary. The early Paleozoic was eminently an oceanic period. During the whole Paleozoic there was, in this country at least, a gradual elevation and enlargement of the continent,

[1] Bull. Geol. Soc. Am., Vol. VIII, p. 113, 1897.; Sci., Vol. V, p. 321, 1896.

slow at first, but rapidly increasing toward the end and culminating in the formation of the Appalachian chain. Concurrently with this there was, almost certainly, a gradual decrease of temperature rapidly culminating at the end in something approaching, at least, a true glacial epoch in the Permian. Similarly, there was probably, during the Tertiary, a gradual elevation and increase of land and diminution of temperature, culminating somewhat rapidly at its end, in the Ozarkian elevation and the Glacial ice sheet. Similar changes occurred at other critical periods, but less conspicuously.

I have been accustomed, in default of any other and more probable cause, to attribute the increase of cold directly to the increase of elevation, although admitting its possible insufficiency. It is this apparent insufficiency that constitutes the only justification of extra-terrestrial theories of Glacial climate, such as Croll's, etc. Recently Professor Chamberlin has contributed to the JOURNAL OF GEOLOGY[1] some admirable and suggestive speculations on the cause of these cycles of climate and of life. According to him, the continental elevation is not the direct, but mainly the *indirect* cause of cold, by the exhaustion of the supply of CO_2 in the air by continuous rock-decay during these land-periods. This supply is supposed to be restored from the interior of the earth through fissures, etc., produced by the commotions of these times. He, moreover, correlates these changes in elevation and in temperature in a most suggestive way with alternating richness and poverty of life and corresponding alternations of limestones and sandstones. I cannot, of course, dwell on these very suggestive views, but only draw attention to the fact that the cycles of which Professor Chamberlin speaks correspond to the *smaller* or subordinate cycles spoken of on pages 536 and 537, and *not* to the great cycles separated by critical periods and constituting eras. Nevertheless, there is no reason why similar causes acting with greater intensity at long intervals should not determine the greater cycles also.

3. *Cycles of geographic diversity of organic forms and of rates of*

[1] JOUR. GEOL., Vol. VI, pp. 597, 609, 1898.

evolution.—We have already explained in a previous paper[1] how, during the course of a cycle, the geographical diversity of organic forms in isolated regions becomes greater and greater indefinitely as long as isolation continues, until finally synchronic correlation of strata in different regions becomes difficult or impossible. But that during critical periods (and to less degree at other times) there occur wide migrations and mingling of faunas and corresponding obliteration of geographical diversity, only to commence again with new isolations and a new geographical diversity increasing again with time. Thus there are alternations of increase and obliteration of faunal diversity. This idea has an important bearing on the doctrines of synchrony and homotaxy. At the beginning of a great cycle immediately after a critical period, geographical faunas commence, as it were, all abreast; synchrony and homotaxy are now in harmony. As time goes on, the newly mingled but re-isolated faunas develop in different directions and at different rates, become more and more divergent in character, and more and more different in grade of evolution. Synchrony and homotaxy become more and more discordant, until at the end of the cycle it becomes extremely difficult or even impossible to correlate strata of different countries synchronically. Then there comes another critical period of widespread oscillations of crust and readjustment to new conditions of equilibrium with accompanying oscillations of temperature and wide migrations of species and mingling of faunas and floras, hastening the steps of evolution everywhere, but obliterating geographical diversity, and, as it were, evening up again synchrony and homotaxy, only to commence a new cycle by re-isolation.

An attempt is made to roughly represent this process by a diagram (Fig. 3). In this diagram two cycles are represented. In the first, Europe is ahead, and increasingly so as the cycle goes on, and Australia is most lagging. In the second, North America is ahead. In each the divergence between synchrony (the full waving lines) and homotaxy (the horizontal dotted

[1] Bull. Geol. Dept. of Univ. of Cal., Vol. I, p. 314, 1895.

lines) becomes greater and greater until the end of the cycle, when there comes a critical period of wide migrations of species (represented by the horizontal arrows), a mingling of faunas, a fiercer struggle for life, together with the more active operation of other factors of evolution, and a consequent hastening of the steps of evolution everywhere, but especially in the lagging areas, to a more or less even general line. In the second cycle

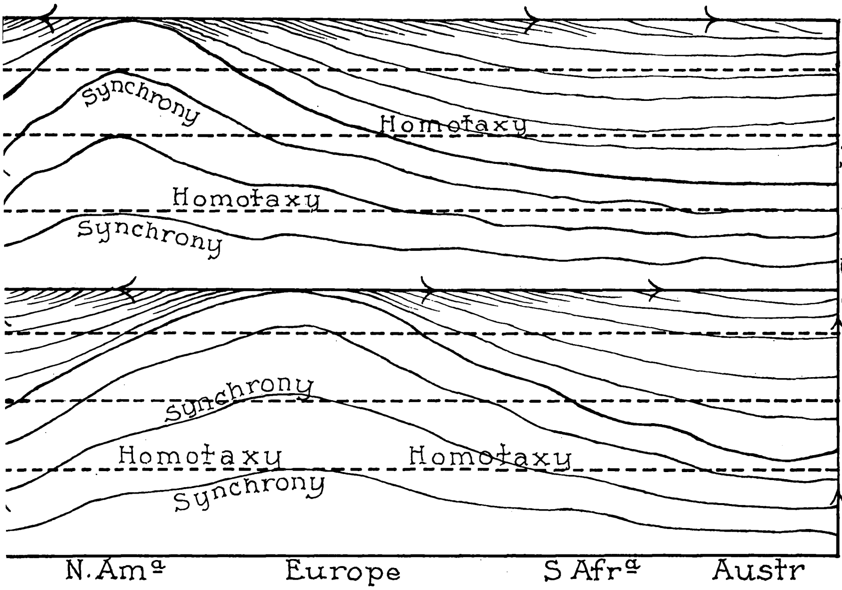

FIG. 3. Diagram showing the general relations of synchrony to homotaxy in geological times. Full lines represent the same time in different places (synchrony). Horizontal dotted lines represent equal stages in evolution (homotaxy).

the same process begins and progresses, except that now America is ahead, and increasingly so until the next crisis; when the synchronic lines are again evened up to parallelism with the homotaxic. If it were not for these occasional evening-ups a general geological history based on organic remains would be impossible.

The whole process may be likened to a long army line marching abreast over a broken country, led by officers, who may be compared to the dominant types. Soon the line

becomes irregular, and more and more so, until it is no longer discernible and all seems confusion. At certain intervals the leaders run along the lines hastening up the laggards until the line is re-formed. But the re-formed line again soon becomes irregular and falls into confusion, and is again re-formed, and so on.

Of course partial and more or less local readjustments of synchrony and homotaxy take place at intermediate times at the end of subordinate cycles. Sometimes in the general readjustment some locality may be left out. This is the case with Australia today. The last wide migrations and minglings of faunas and obliteration of geographical diversity, viz., that during the Quaternary, did not reach Australia, and therefore its fauna is still far behind in the race of evolution.

4. *Cycle of topographic forms by erosion.*— But there is still another cycle, and one with which we are especially concerned here, viz., the *cycle of erosion-forms.* Every critical period is a time of the formation of great mountain ranges, and the crisis is usually named after the mountain range which forms its most conspicuous monument. Thus we have the Appalachian revolution, closing the Paleozoic; the Cordilleran, closing the Mesozoic. The pre-Cambrian crisis might well be called the Laurentian, and the one we are now specially dealing with, viz., the Quaternary or Ozarkian, might well be called the Basin Ranges revolution; for not only the basin ranges, but also the Sierra Nevada, the Coast Ranges of California, and the Mt. St. Elias Range of Alaska were either formed or else rejuvenated at that time.

Thus with every critical period there are new mountains formed and old ones rejuvenated; new lands formed by emergence of sea bottoms and old ones elevated or depressed. Thus new constructional forms are made and a new cycle of destructional or erosive forms inaugurated. These forms pass gradually through the stages so graphically described by Professor W. M. Davis and others, the final result being the so-called *peneplain.* Of course, there are subordinate, intermediate, and more local cycles; and therefore at the end of the great cycle

we may have examples of both old and new topography. But in any case a critical period, being the beginning of a new great cycle, after such a period we have only or mainly new topography. This is the true and conclusive answer to Professor Tarr's objection to Professor Davis' far-reaching deductions from the supposed discovery of the remnants of former peneplains. Professor Tarr objects that if there be any such former peneplains there ought to be peneplains formed now and in the present geological epoch—that the very foundation of geology as an inductive science consists in the use of causes and processes now in operation as the basis of reasoning on phenomena of earlier times. Yes, *causes* and *processes* now in operation, but not *results* and *forms* now existent and produced in the present epoch. Causes and processes are constant, or nearly so, but resulting forms pass through a regular cycle of evolution-changes. Now the *last cycle is just commenced.* We must wait at least a few millions of years before we can expect to find peneplains made out of the recently inaugurated and highly emphasized topographic forms. As a note of warning against hasty generalizations Professor Tarr's paper cannot be too highly commended. We are all too apt to be carried away by a new idea. It is apt to become a fashion of thought for which we are ever seeking confirmation; and in all complex and imperfectly understood questions, what we seek earnestly for we are very apt to find. It is possible, yea, it is probable, that the peneplain idea has been overworked; that many of these ancient peneplains exist only in the fervid imagination of the too ardent geologist. Nevertheless, the principle is a true one and undoubtedly a very fertile one. Geological history has heretofore been based almost wholly on the results of sedimentation. It is time that it should be based also, and equally, on the results of erosion. These results may be more difficult of interpretation, but difficulties ought only to stimulate investigation.

Is the Ozarkian Tertiary or Quaternary? Finally, we are now prepared to return to the question of place of Ozarkian in the geological classification. After what has been said the answer

to this question is plain. Critical periods, as I have shown in previous papers, are the great landmarks separating the primary divisions of geological time—the eras. They are the comparatively fixed points between which we correlate periods as best we can by comparison. Now, if the Quaternary be indeed one of these and the last, then it is evident that the Ozarkian, being a time of great elevation and enlargement of continents, and therefore a period of lost record, belongs par excellence to that period. It is the most important and characteristic part, and the part which determined the whole succession of changes which inaugurated a new order of things, viz., Present; a new era, viz., the Psychozoic. The Tertiary was a period of comparative quiet, of gradual changes, and abundant life. The Ozarkian commenced the series of evolutionary changes which inaugurated a new era and is the most characteristic and important epoch in the series.

That the Ozarkian belongs to the Quaternary, therefore, is certain. But the question still remains: to what era should we attach the Quaternary? Upham thinks that to be consistent I ought to put it in the Psychozoic, because *man* was introduced in the Quaternary.[1] On the contrary, I believe it should be allied with the Cenozoic. The Permian, too, is a transition. revolutionary, critical period between the Paleozoic and Mesozoic, But after much discussion it has been put with the Paleozoic. The Laramie is the transition, revolutionary, critical period between the Mesozoic and Cenozoic. Again, after long discussion, it has been put in the Mesozoic. So, also, the Quaternary is the transitional, revolutionary, critical period between the Cenozoic and Psychozoic. After some discussion it will undoubtedly be put in the Cenozoic with the Tertiary. It is true that man, the characteristic dominant type of the Psychozoic, was introduced in the Quaternary. But here, also, the analogy with other critical periods holds good. A new era begins when the readjustment and the new order is established. Reptiles were introduced in the Permian, but the reign of reptiles did not

[1] Am. Nat., Vol. XXVIII, p. 980, 1894.

begin until the Trias. Mammals were introduced in the Mesozoic, and even true mammals—eutheres—probably in the Laramie, but the reign of mammals did not begin until the Tertiary. So, also, man was introduced in the Quaternary and possibly even in the Pliocene, but for a long time he struggled doubtfully for mastery with the great beasts of that time. His supremacy was not established until after the Glacial epoch, *i. e.*, with the Psychozoic.

All I insist on, however, is that the Quaternary, wherever it is put, must all go together. It must not be split and its most characteristic part separated and put in the Tertiary. There may be, indeed, some good reasons for putting it *all* in the Tertiary, and analogy will bear this out. For example, it is customary to make three periods in the Carboniferous, viz., the Mississipian, the Coal Measures, and the Permian, but there is a growing tendency to unite the Permian with the Coal Measures as its uppermost transitional stage. Again, we may divide the Mesozoic into Triassic, Jura, Cretaceous, and Laramie, but it is more usual and probably best to unite the Laramie with the Cretaceous as its uppermost transitional stage. So, also, it is customary to divide the Cenozoic into two periods, Tertiary and Quaternary, but it may possibly be better to regard the Quaternary as the final transitional stage of the Tertiary, and thus to divide the Tertiary into four epochs, the Eocene, Miocene, Pliocene, and Pleistocene. All I insist on is that its most characteristic part and that which determined the whole series of changes characteristic of this time should not be separated from the rest.

A PLEA FOR PSYCHOZOIC AS AN ERA.

I again take occasion to insist on the present, as the beginning of a new era—the Psychozoic—separated from the Cenozoic by the last great critical period, the Quaternary. This must be so if the Quaternary be indeed a critical period comparable with those that separated the previous eras. That it is such is shown by the fact that it has all the characteristics of such periods. It is characterized (1) by widespread oscillations of

the earth's crust; (2) by the formation or rejuvenation of great mountain ranges; (3) by the formation of new constructional forms, and the inauguration of a new cycle of erosion forms; (4) by great climatic oscillations; (5) by wide migrations and minglings of faunas and floras, and fiercer struggle for life, and rapid changes of organic forms by wholesale destruction of old forms and evolution of new forms; (6) by more rapid steps of evolution, but a partial obliteration of previous geographic diversity, and the inauguration of a new cycle of increasing diversity; and (7) by the introduction of a new dominant type —man, who is now becoming more and more the great agent of change in the new era, especially in organic forms.

There can be no doubt that we are now in the midst of a change more sweeping and rapid than has ever before taken place in the history of the earth, but which we imperfectly appreciate because we are in the midst of it, and therefore lose the perspective. Why then should we hesitate to recognize that the present is indeed one of the prime divisions of geological time? It is more: it is that which alone gives significance to all that precedes.

JOSEPH LE CONTE.